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ESD-TDR-63-343

EFFECTS OF DIFFERENTIAL VALUE AND EXPOSURE

TIME UPON THE DETECTION AND MEMORY
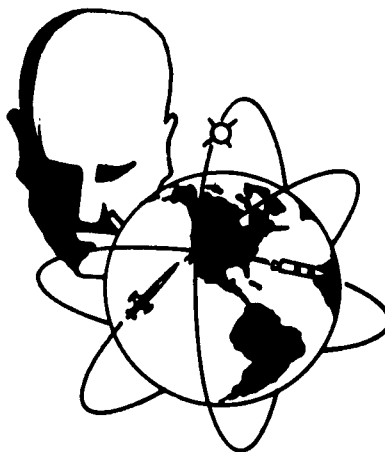
SYMBOLS IN A VISUAL SEARCH TASK

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Technical Documentary Report No. ESD-TDR-63-343

DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
BEDFORD, MASS.

June 1963

1963

FOREWORD

This report was prepared by Dr. Harvey A. Taub of the Institute of Environmental Psychophysiology, University of Massachusetts under Dr. Warren Teichner, Project Scientist.

The work was performed under USAF Contract No. AF19(628)-290, in support of Project 9674, Task No. 967404, "Information Processing under System Stress". The contract was administered by the Applications Division, Decision Sciences Laboratory, Deputy for Engineering & Technology of the Electronic Systems Division. Dr. John Coules served as contract monitor and contributed to the planning of the work.

ABSTRACT

The accuracy of reporting data from briefly-exposed, multi-target symbolic displays in which the value or importance of the targets varies within the display was shown to vary inversely with the differential ratio of value of the targets. The data also suggested that (1) an increase in differential ratio does not facilitate the reporting of more important targets, but rather decreases reports of less important ones, (2) the difference in accuracy of report to high and low valued targets varies directly with exposure time up to 2.5 sec. for the display used with 1.5 sec. as a possible optimum. The results are consistent with the hypothesis that differential value produces a selective recall from short-term memory storage.
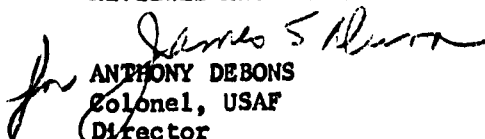
REVIEWED AND APPROVED FOR PUBLICATION:

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Introduction

The purpose of the present experiment was to investigate the effects of the differential value of symbols upon the perception and short term memory of these symbols in a visual search task. The experiment was designed to extend the basic knowledge applicable to the prediction of performance in monitoring and complex detection situations, such as exist in air traffic control and radar defense systems. In these situations, observers must search for, detect, and report the presence of symbols which represent objects of varying importance. For example, in a military radar system, the detection and report of a hostile missile will generally be more important than a report of the friendly aircraft within the area. Since both types of information are valuable, but to different degrees, it is desirable to know if the higher valued symbols will be reported more accurately than those of lesser value, and if the difference in response to the symbols varies with the difference in importance or value.

Until recently, studies of the span of attention or perception were concerned with tasks that did not involve search. The stimuli (dots, colors, letters, or numbers) were presented for a short duration and in a fixed location. Observers were not required to search for the symbols, but only to estimate the number of similar stimuli (Kaufman, Lord, Reese, and Volkman, 1949; Woodworth and

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Schlosberg, 1954) or to report the names of the different stimulus categories (Anderson and Fitts, 1958; Sperling, 1960; Woodworth and Schlosberg, 1954). The general finding of these studies was that there is an upper limit to the number of categories that can be correctly reported. This upper limit varies with the type and complexity of the stimuli (Glanville and Dallenbach, 1929; Woodworth and Schlosberg, 1954). Thus, with any particular type of stimulus, increasing the number of categories beyond the upper limit produces a decrease in the percentage of stimuli that can be accurately reported. Using information transmission as the dependent measure, Anderson and Fitts (1958) found that the amount of transmission increased first and then decreased as the number of stimulus categories was increased.

In his review of the literature, Miller (1956) noted that a distinction must be made between the span for perception and the span for memory. This distinction implies that the number of categories that can be identified correctly depends both upon what can be perceived within the duration of exposure, and what can be remembered at the time of report. Support for this notion was provided by Sperling (1960) who demonstrated that more information was available to subjects immediately after termination of the stimulus than could be remembered and later reported. Further, Anderson and Fitts (1958), Brown (1954, 1958), and Sperling (1960) have found that there was more accuracy for those symbols which were recorded first. Thus, the number of accurately reported symbols

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is determined not only by the number of stimuli perceived, but also by the serial position of a particular category and the time elapsed before that category is reported or recorded.

Teichner, Reilly and Sadler (1961) were the first to attempt a direct test of Miller's hypothesis using a visual search task. The stimuli were slide projections which were exposed for a short period of time. Each slide contained a number (load) of different letters (categories) and repeated each category a number of times (density). The task of each S was to search, detect, and report the different categories which were displayed. It was assumed that perception included the search, detection and storage of information (memory storage) which occurred during the exposure of the slide. Conversely, the concept of short term memory was assumed to include the recall and report of letters from storage following the cessation of the slide. It was assumed further that the relative differences in number of letters perceived and the number reported may be investigated by varying the amount of information to be remembered (memory load), i. e. , the less the memory requirement, the closer the approximation to pure perception or detection. Two groups of subjects were used. The first (the counting group) had a relatively small memory load as they were required to report only the number of the categories (e. g. 4, 5 or 6). The second group (the naming group) had to report the names of each category they detected (e. g. A, B, C). A comparison of the number counted with the number named was used to determine the effects of additional

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memory loads. An analysis of the difference in performance between these two groups showed that the number of letters reported varied inversely with size of the memory load. These results, in agreement with the previously cited investigations which did not involve search (Glanville and Dallenbach, 1929; Sperling, 1960), also suggested that humans can receive more information than they can recall.

With respect to the identification of distinct categories, Teichner, Reilly and Sadler (1961) found that the percentage of correct identifications was inversely proportional to the number of categories (load). This result also agreed with those obtained in the simpler non-search tasks (Glanville and Dallenbach, 1929; Sperling, 1960; Woodworth and Schlosberg, 1954).

Another variable of considerable importance in the search task is exposure time. Since the accuracy of the report is dependent upon both perception and memory (Teichner, Reilly and Sadler, 1961), performance should improve as exposure time is increased until the limit of the memory span is reached. This has been confirmed by Teichner and Sadler (1962) who found that accuracy, as measured by percentage correct, was inversely related to load and directly related to exposure time. It was also found that accuracy in the letter-search task was a negatively accelerated increasing function of exposure time with an asymptote at about 2.5 seconds. In general, increases of viewing time from 2.5 seconds to 5.0 seconds produced only small increases in accuracy of reports. The importance of this variable in aiding performance is emphasized by the finding that with an exposure

time of 5.0 seconds, the percentage correct with a load of six categories was over 90%, while with an exposure of 0.5 seconds, the accuracy was only about 40%.

There have been no studies with differential values of stimuli that are directly pertinent to the present search task. The only types of investigation that have utilized differential values were those of two-choice gambling situations (Taub and Myers, 1961), and forced choice detections of a known signal (Tanner and Swets, 1954). Although these two kinds of experiment have used distinctly different tasks, both apply the same theoretical terms and a common concept of maximizing the expected value of performance. In order to maximize expected values, i.e., to win as many coins, points, or chips as possible, Ss must employ certain response strategies and shift these strategies as the values of the correct responses shift. Thus, Taub and Myers (1961) found that when Ss had to predict which of two lights would come on, they chose the one with the higher expected value more than 50% of the time. Further, the difference in percentage prediction of the two lights increased as the difference in the expected values increased. Similarly, Tanner and Swets (1954) found that when Ss were forced to report whether a near-threshold signal had appeared, the number of false alarms (reports of detection when no signal had appeared) increased as the importance or value of a detection increased.

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Statement of the Problem

The literature does not contain direct information concerning the effects of differential value upon detection and short term memory. Since most detection situations involve objects of varying importance, there is a need for this information. In general, helping to fill this need was the major objective of the present study.

Although studies of differential values have not used value in precisely the same way as it was used in the present experiment, the results of these studies constituted the only related data and were used as a basis for working hypotheses. Thus, it was expected that to maximize performance, $\underline{Ss}$ would attempt to search for, detect and report the higher valued symbols before those of lesser value. Thus, initial responses should vary and be directly dependent upon the relative value of the symbols.

Accuracy of performance with both high and low valued stimuli should also vary with differential value. Since it has been found that there is a higher accuracy for those stimuli reported first (Anderson and Fitts, 1958; Brown, 1954; Brown, 1958; Sperling, 1960), it was predicted that performance would be more accurate for the higher valued stimuli. Further, the results of studies which showed that $\underline{Ss}$ can remember and report only a limited and fairly constant number of stimuli under each particular set of load and exposure conditions (Glanville and Dallenbach, 1929; Sperling, 1960; Teichner, Reilly and Sadler, 1961) led to the prediction that over-all accuracy would not be greatly affected by changes in value. Thus, every increase in

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accuracy for the higher valued stimuli should be accompanied by a corresponding decrease in performance for the lower valued stimuli. Accuracy of performance for the higher valued stimuli should vary directly with the relative differences in value, while performance for the low valued letters should vary inversely.

No definite predictions were made concerning the effects of exposure time since there was no pertinent information relating this variable to differential value. Previous studies (Teichner and Myers, 1961; Teichner and Sadler, 1962) would lead to the expectation that the accuracy of identification would depend on this factor. It seemed intuitively acceptable that the effects of the value variables would interact with exposure time.

No predictions were made concerning the effects of value and ratio of value upon the number of false reports. Although the literature suggests that false reports will vary as a function of value when an ambiguous near threshold signal must be detected, there was no direct information concerning the effect of value with symbols that are not ambiguous. The symbols used in this experiment were letters of the alphabet which were assumed to be clearly discriminable and unambiguous.

Thus, two major groups of predictions concerning value can be made:

1. $\underline{Ss}$ should make more initial responses, and correct identifications of higher valued categories than of the lower valued categories.

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2. The above differences should vary directly with the size of the ratio of value. The prediction of the shape of this interaction was that response to the higher valued letters should increase with the size of the ratio, while comparative responses to low valued stimuli should decrease.

The specific purpose of this experiment was the test of the above predictions. This was achieved in a situation comparable to that of Teichner, Reilly and Sadler (1961) which in addition permitted the evaluation of the effects of value, load, and exposure time and their possible interactions.

Method

Subjects

The 120 Ss were male volunteers enrolled in the summer

session at the University of Massachusetts. All Ss competed for

monetary prizes.

Apparatus

The stimuli consisted of 50 slides with white letters on a black

background. The slides varied in number of categories (load) with

each letter of the alphabet representing a category. The five levels

of load were 4, 6, 8, 10 and 12 letters per slide. Each level of load

was replicated 10 times with a different random sample of the alphabet.

Density, or the number of times a letter was repeated on each slide,

was always constant at two.

To allow for a comparison of values, a distinction was made

between the first and second halves of the alphabet. Each letter from

A through K was worth one unit of value, while the letters P through

Z had a different value. In order to provide a break between the two

halves of the alphabet, the letters L, M, N and O were not used on

any of the slides. This provided two populations of category value,

each containing eleven letters.

All slides were designed to contain an equal number of letters

from both halves of the alphabet. For example, Figure 1 presents an

8-load slide which contains four letters from the first half and four

letters from the second half. Each slide was constructed by first

randomly choosing the letters and then randomly assigning each one

to a location within a 10 x 10 matrix. Following selection and location,

capital letters were typed on blank cards using typewritter spaces as

matrix cells. These cards were then photographed and made into

2 x 2 inch projection slides with white letters on a black background.
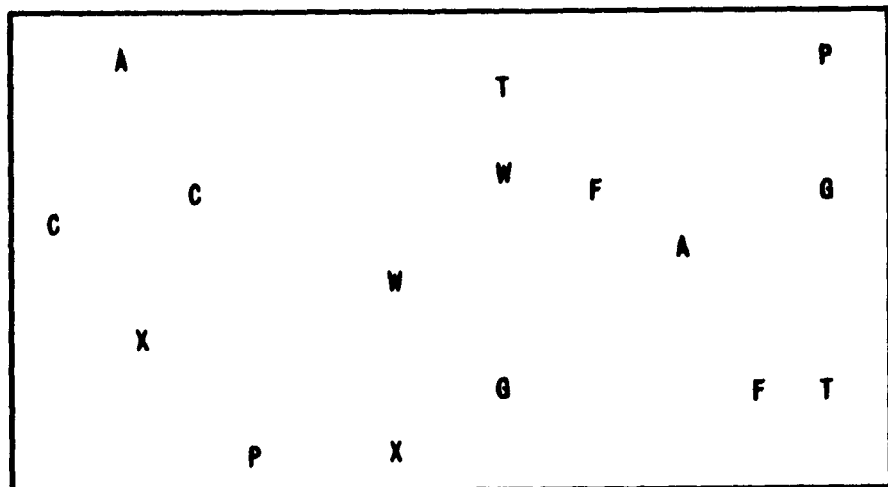
Fig. I   A sample slide with 8 categories.

A Revere automatic slide projector with an externally mounted

shutter presented the slides and two electronic timers controlled the

exposure times and interslide intervals. The projected size of the

slide was 40 x 60 inches, while the projected size of the letters was

1 inch. $\underline{S}$s sat in student arm-type chairs in groups of one to four such

that the average distance from their eyes to the projected letters was

96 inches. Ss performed under red illumination provided by two 25 watt light bulbs and reported their answers on prepared data sheets.

Although the experimental room was able to accommodate four Ss, the periodic shortage of volunteers made it necessary sometimes to run fewer per session. In those conditions where less than four Ss were run in a single session, care was taken to assign each S to a different seat. This eliminated the possibility of response biases for a particular part of screen due to seating position.

Procedure

The 120 Ss were randomly assigned to 12 equal groups as shown in Table 1. The design is a 3 x 4 x 5 x 2 factorial with Exposure Time and Ratio of Value as "between effects" and Load and Category Value as "within effects." The exposure times were 0.5, 1.5, and 2.5 seconds; the four differential ratios of value were 2:1, 4:1, 8:1 and 16:1. Additional groups using equal value (1:1), were run to be used in an evaluation of initial biases to the two halves of the alphabet. Load refers to the number of different categories per slide (4, 6, 8, 10 and 12), while Category Value refers to the two populations of categories which were designated as high and low value for each of the ratios.

Each S served for approximately 40 minutes. During the first 15 minutes he received general instructions and training. The purpose of this training was to provide him with practice in seeing slides, in writing answers during the interslide interval, and in differentiating between the halves of the alphabet. The training period consisted of

Table 1
Summary of experimental design

EXPOSURE TIME (SECONDS)	RATIO OF VALUES	Ss	CATEGORY VALUE		
			HIGH 4 6 8 10 12	LOAD	LOW 4 6 8 10 12
0.5	2:1	8			
	4:1	8			
	8:1	8			
	16:1	8			
1.5	2:1	8			
	4:1	8			
	8:1	8			
	16:1	8			
2.5	2:1	8			
	4:1	8			
	8:1	8			
	16:1	8			

thirty-eight slides which were presented for 0.5 second each with an interslide interval of 3 seconds. Each slide contained only one letter. The S's task was to search the screen, locate the letter, and then write down a 1 or 2 to designate whether the letter was in the first or second half of the alphabet. The use of the shortest experimental exposure time and the short interval between slides was intended to force Ss to respond quickly and to minimize the time available for differentiating the halves of the alphabet. Although 38 slides were presented during training, a preliminary investigation of this task showed that the presentation of the first 10 slides was sufficient to bring all Ss up to 100% accuracy.

Initial instructions explained the specific purpose of the practice session and the nature of the division of the alphabet, but did not reveal any information concerning the exact nature of the experimental period. All instructions for the experimental period were given immediately following practice. At this time E explained that the division of the alphabet would be the same, i.e., A-K and P-Z, that each slide would always contain more than one letter, and that S was now required to report the names of the actual letters that he saw. He was then told the particular ratio of value of his group, that he would receive points for each letter that he reported correctly and that the number of points received for any particular letter was equal to the value assigned to the category population in which it was contained. For example, in an 8:1 ratio group, if the letters A-K were designated as the high value categories and P-Z were the low value categories, then an S would

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receive 8 points for each letter within A-K that he correctly reported and 1 point for each correct report of the letters P-Z.

The only restriction placed on the report of letters was that points would be received only for each different category that was reported. This restriction was necessary since each particular letter on a slide was always repeated twice, i.e., a density of 2. Thus, Ss were instructed to report each letter on a slide just once.

In general, the Ss task consisted of searching, detecting and writing down as many of the displayed letters as possible in order to compile as many points as possible. Although, Ss knew the values of the categories, they were given no knowledge of the load, of the frequency of occurrence of value categories, or of their own results.

All Ss were presented with all 50 slides in the same random order with a 10 second interslide interval. This interslide interval was easily sufficient to permit a report of all letters on the slide. Following the experimental period, each S was asked to record the particular way in which he searched the slide.

To eliminate possible biases to the first or second half of the alphabet, the ratio of values were counterbalanced for the two halves. Thus, 4 Ss within each group of 8 had the first half of the alphabet as the higher valued categories, while the other 4 had the reverse.

A prize of $5.00 and two prizes of $2.00 were awarded to the three Ss within each group who had the highest sum of points.

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Results

Analysis of Differential Value

The data were analyzed in terms of three measures: a) the per-
centage of high and low valued categories which were correctly
reported, b) the percentage of times that the initial response was a
high valued letter, and c) the number of false reports of high and low
valued letters, i.e., the report of a letter when it was not displayed.
The analyses of these measures were concerned with the effects of
differential value and did not include the results for the 1:1 groups.

The results for the percentage correct for each condition were
obtained from the combined number of correct reports over the 10
slides in each of the levels of category. An analysis of variance was
performed on the arc sine of these data. The results of this analysis
are summarized in Table 2 where it may be seen that the main effects
of Exposure Time, Load, and Category Value were all significant at
$P < .01$, while Ratio of Value was significant at $P < .05$. Of the first
order interactions, Load X Exposure Time and Category Value X
Exposure Time were both significant at $P < .01$, while Category
Value X Ratio of Value was significant at $P < .05$. The rest of the
first order interactions and all of the higher order interactions were
non-significant sources of variance.

Figure 2 presents the accuracy of performance for the Load X
Exposure Time interaction. The fact that this interaction was

Table 2

Summary of analysis of variance for accuracy of report of high and low valued categories

SOURCE	df	MS	F
BETWEEN Ss	95		
EXPOSURE TIME (E)	2	3624.250	318.626**
RATIO OF VALUE (R)	3	405.267	3.955*
E x R	6	209.850	2.050
Ss/E x R[a]	84	102.390	
WITHIN Ss	864		
LOAD (L)	4	26821.525	1431.092**
CATEGORY VALUE (V)	1	8552.100	88.170**
L x V	4	53.900	1.914
L x E	8	1411.525	75.313**
L x R	12	8.008	.427
V x E	2	909.200	9.374**
V x R	3	318.833	3.287*
L x V x E	8	43.850	1.559
L x V x R	12	7.650	.272
L x E x R	24	11.508	.614
V x E x R	6	88.983	.917
L x V x E x R	24	21.313	.757
Ss x L/E x R[b]	336	18.742	
Ss x V/E x R[c]	84	96.996	
Ss x L x V/E x R[d]	336	28.154	

a ERROR TERM FOR E, R, E x R

b ERROR TERM FOR L, L x E, L x R, L x E x R

c ERROR TERM FOR V, V x E, V x R, V x E x R

d ERROR TERM FOR L x V, L x V x E, L x V x R, L x V x E x R
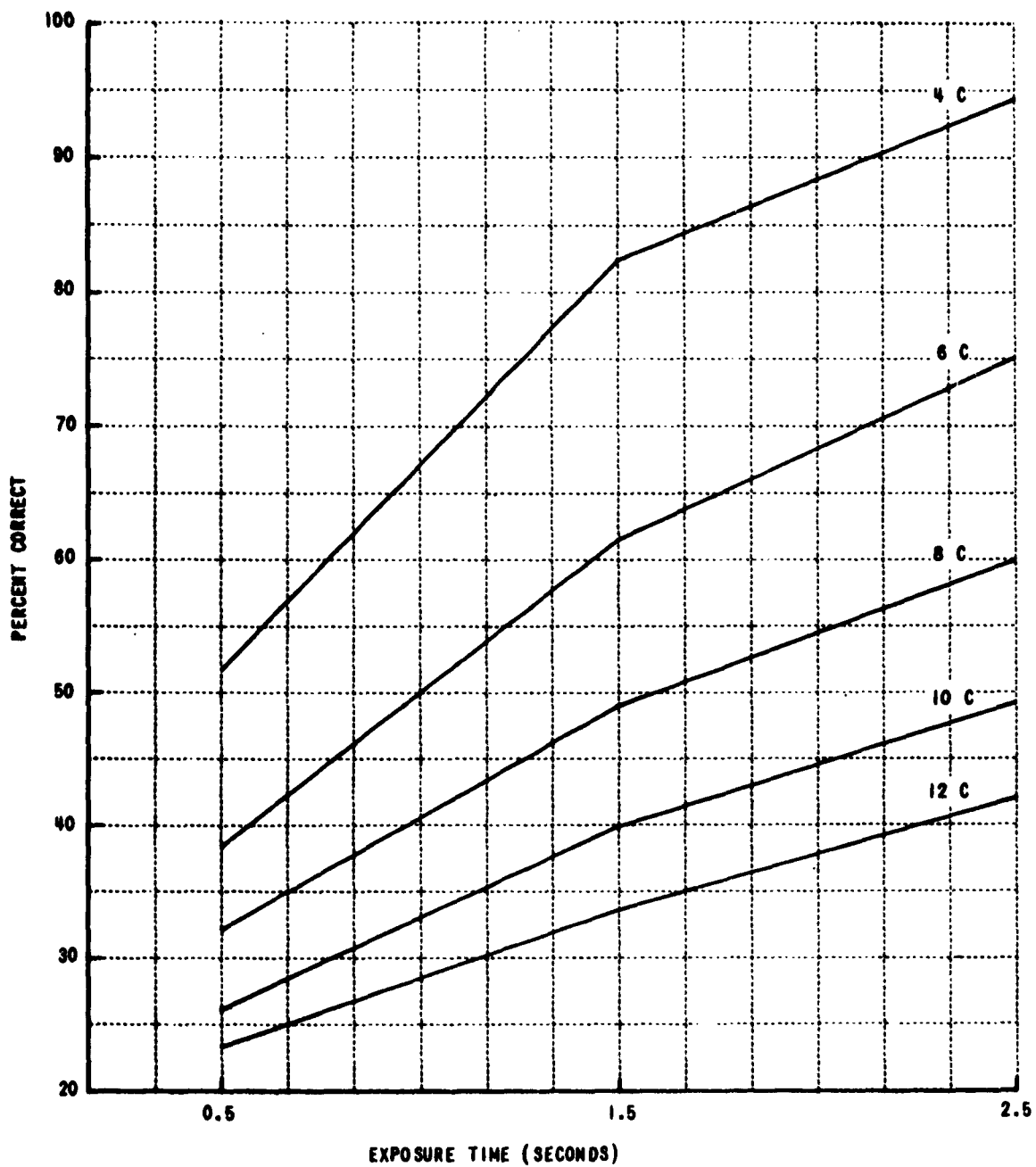
* $P < .05$

** $P < .01$

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Fig. 2   Percentage correct as a function of exposure time with load
(number of categories) as a parameter.

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significant is shown by the increasing differences among loads as exposure time is increased. More simply, the amount of benefit derived from increasing exposure time was inversely related to the number of categories displayed. This figure also shows that percentage correct varied inversely with the number of categories displayed (load) and directly with the length of exposure.

Figure 3 shows accuracy of performance as a function of ratio of value, with category value as a parameter. Although the 1:1 groups were not used in the analysis of variance, these data are included in the figure to illustrate the level of performance for equal valued categories. A comparison of the 1:1 condition with the rest of the groups shows the strong effect of the addition of differential Category Value, i.e., accuracy of report for the high valued categories was always greater than for the equal and low valued categories.

The significant main effect of Ratio of Value may also be seen from Figure 3. Although there was a slight increase in over-all accuracy with the 2:1 ratio, performance decreased as the ratio was increased to 8:1. The increase in percentage correct at 16:1 did not bring performance back to the level attained with the 1:1 and 2:1 ratios. Inspection of the Category Value X Ratio of Value interaction (omitting the 1:1 data) indicates that the decrement in over-all performance was largely due to a reduction in accuracy for the lower valued categories as the differential ratio of value increased. Thus, the figure suggests that the interaction may not represent an increase in accuracy of high valued letters, but a decrease in performance for the low valued letters.
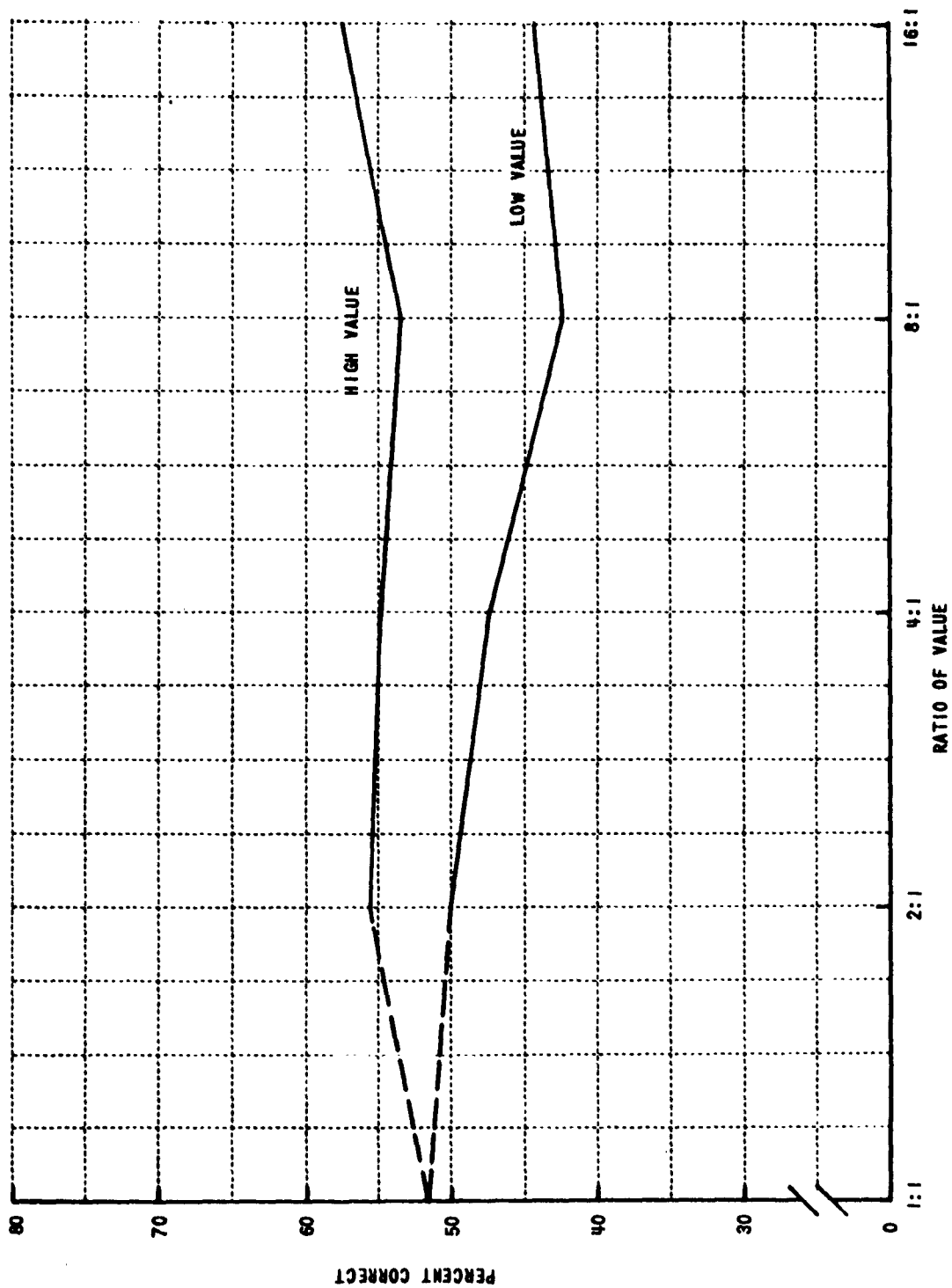
Fig. 3   Percentage correct of high and low valued categories as a function of ratio of value.

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Further evidence for this suggestion was obtained from the results of Student's t tests on the arc sine transformation of data on selected points within each of the high and low value curves. In each of these tests, a comparison was made between the 2:1 ratio group and the group that was most different in accuracy. For the high valued letters, the 16:1 group did not perform with a greater accuracy than the 2:1 group (t = .542, df = 138) which suggests no change in trend,; whereas for the low valued letters, performance was poorer at 8:1 than at 2:1 (t = 2.14, df = 138, p < .05) which suggests a decreasing accuracy with increasing ratio up to 8:1.

Figure 4 presents the interaction of Category Value with Exposure Time. It can be seen from this figure that the difference in percentage currect between high and low valued categories increased directly with exposure time. The divergence of the lines suggests that an increase in exposure time gives greater benefit to performance with high valued categories than to performance with the low.

The initial response data were based on a total of 10 possible responses in each condition. Unlike total percentage correct, the data for the high and low valued initial responses did not vary independently, i. e., the scores for the low-valued responses were equal to the difference between 100% and the percent of high values responses made. Since this was the case, an analysis of variance was performed only for the initial responses to the high valued letters. Table 3 presents a summary of the analysis of variance performed on the arc sine transformation of these data. This table shows that the only effects that
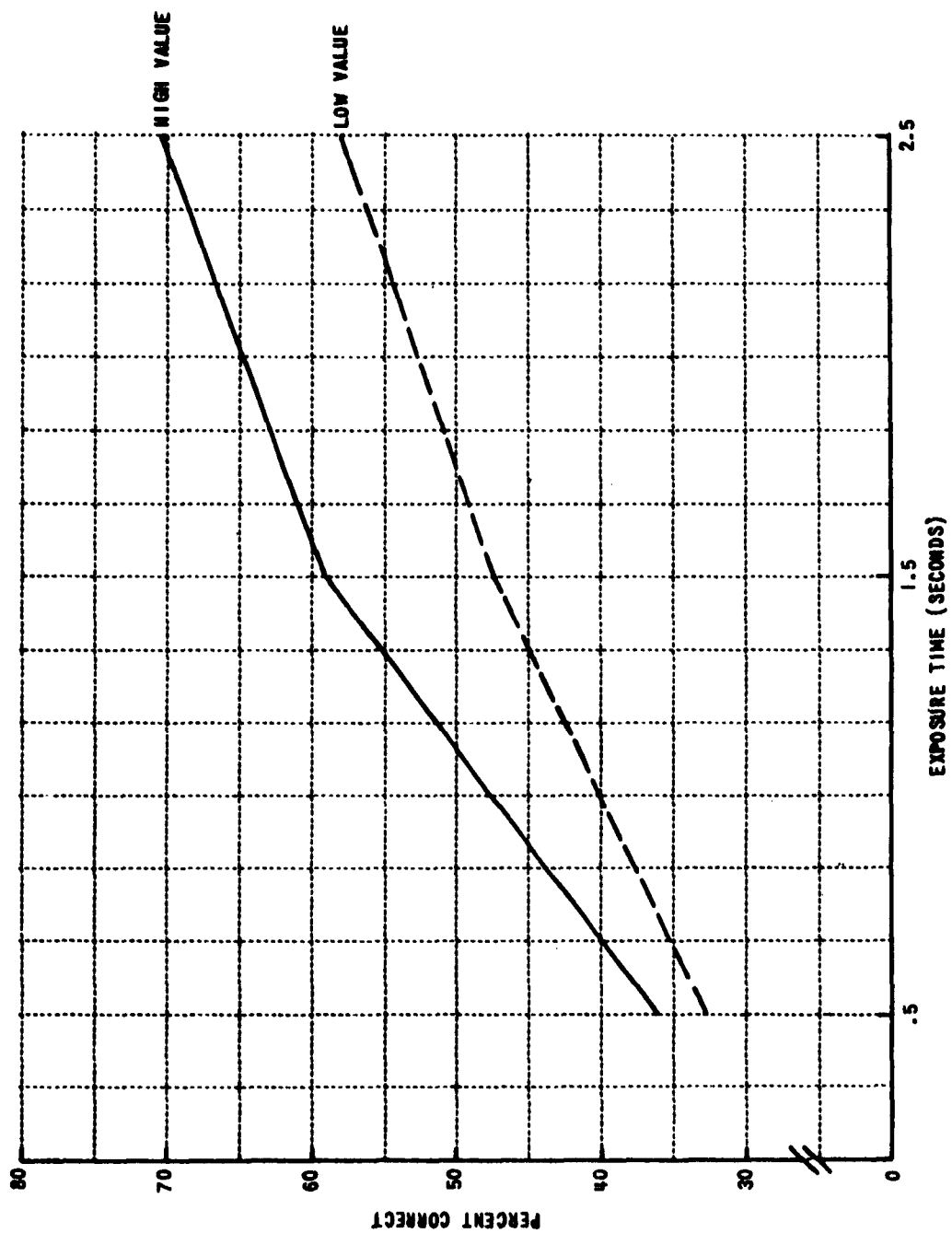
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Fig. 4 Percentage correct of high and low valued categories as a function of exposure time.

Table 3
Summary of analysis of variance for initial responses of high valued categories

SOURCE	df	MS	F
BETWEEN Ss	95		
EXPOSURE TIME (E)	2	1180.65	3.315*
RATIO OF VALUE (R)	3	2165.60	6.080**
E x R	6	433.85	1.218
Ss/E x R	84	356.17	
WITHIN Ss	384		
LOAD (L)	4	108.53	1.008
L x E	8	105.20	.978
L x R	12	94.70	.880
L x E x R	24	94.53	.878
Ss x L/E x R[b]	336	107.62	

a   ERROR TERM FOR E, R, E x R

b   ERROR TERM FOR L, L x E, L x R, L x E x R

*   P<.05

**   P<.01

were significant were the main effects of Exposure Time (P < .05) and Ratio of Value (P < .01).

Figure 5 shows the percentage of initial responses of higher valued letters as a function of ratio groups with exposure time as a parameter. Inspection of this figure shows that all groups made initial responses of high valued categories more than 50% of the time and that the percentage of these responses varied directly with the differential ratio of value. Figure 5 further shows that the initial report of high valued letters was a maximum at 1.5 second exposure. A Tukey WSD test of the means of the arc sine transformation of these results showed that a significantly greater percentage of reports were made at 1.5 second than at .5 second (P < .05). The difference in performance between the means at 1.5 and 2.5 seconds and at 0.5 and 2.5 seconds were not significant. This suggests that 1.5 seconds may be either an optimum exposure time or an asymptote of higher valued initial responses.

Table 4 presents a summary of an analysis of variance on the frequency of false reports. Each S's data for this analysis consisted of the total number of high and low valued false reports summed over all 50 slides. As can be seen from Table 4, the only significant source of variance with this dependent measure was Category Value (P .05). The mean number of false reports of high valued letters was 10.385, while the mean for the low valued categories was 8.635. The non-significant Category Value X Exposure Time and Category Value X Ratio of Value interactions suggest that the differential false report response to category value was not affected by increasing exposure time or ratio.
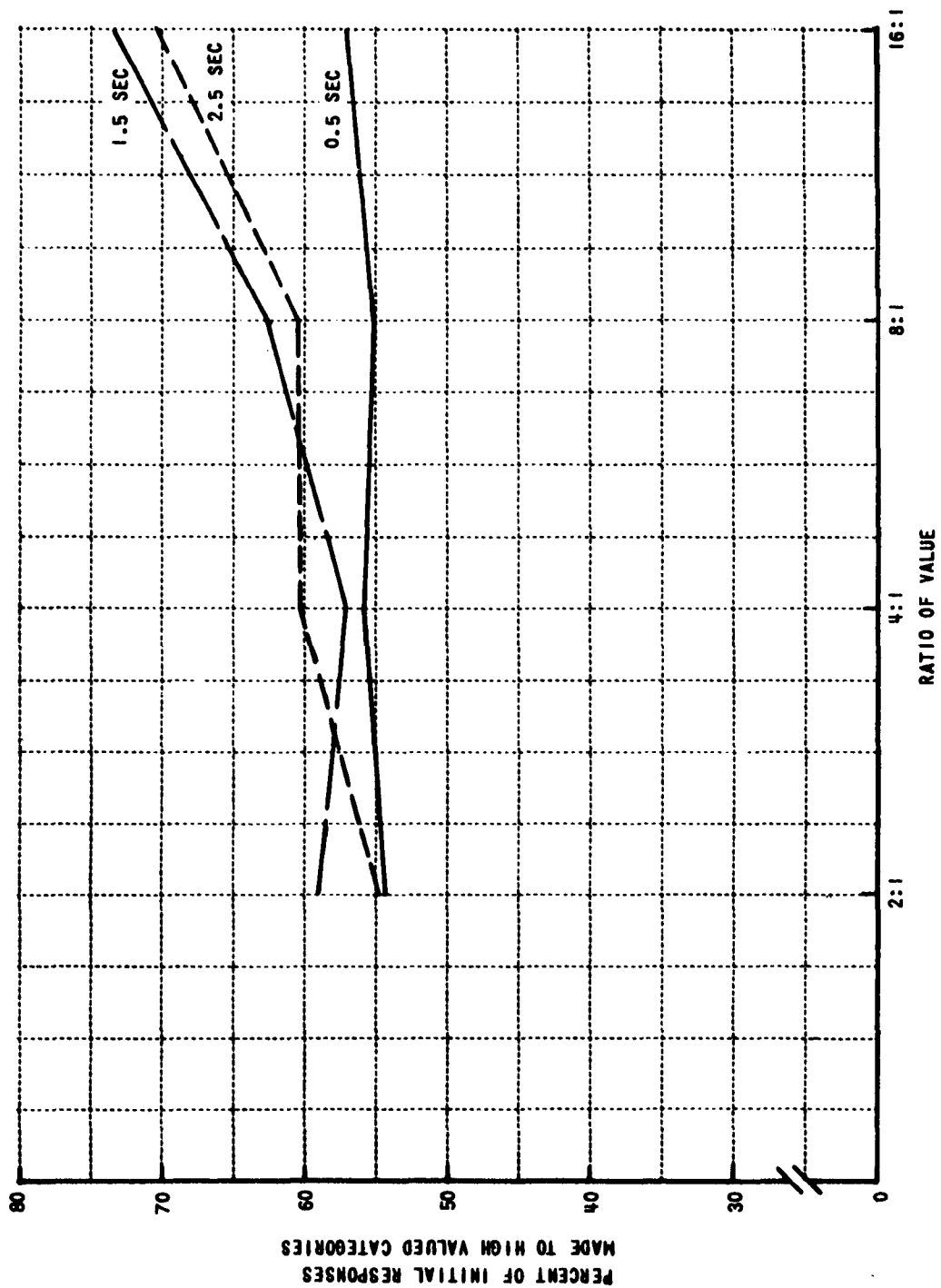
Fig. 5   Percentage of initial responses of high valued categories as a function of ratio of value with exposure time as a parameter.

RATIO OF VALUE

PERCENT OF INITIAL RESPONSES MADE TO HIGH VALUED CATEGORIES

1.5 SEC

2.5 SEC

0.5 SEC

24

Table 4

Summary of analysis of variance for number of
false reports

SOURCE	df	MS	F
BETWEEN Ss	95		
EXPOSURE TIME (E)	2	156.162	2.334
RATIO OF VALUE (R)	3	73.035	1.092
E x R	6	96.113	1.437
Ss/E x R[a]	84	66.903	
WITHIN Ss	96		
CATEGORY VALUE (V)	1	147.00	5.505*
V x E	2	13.42	.503
V x R	3	21.37	.799
V x E x R	6	14.832	.555
Ss x V/E x R[b]	84	26.704	

a   ERROR TERM FOR D, R, E x R

b   ERROR TERM FOR V, V x E, V x R, V x E x R

*   P<.05

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Table 5 presents a summary of the responses to the question con-

cerning the method of search behavior. This table represents the three

Table 5
Summary of search methods employed by
each subject at each exposure time

EXPOSURE TIME	METHODS OF SEARCH		
	RESTRICTED AREA	ENTIRE SCREEN	SCANNING
0.5	26	6	8
1.5	8	3	29
2.5	3	0	37

general classes of responses that were made by the S̲s̲.   The "restricted

area" responses refer to statements indicating an inability to search

more than a small portion of the slide, e. g. , "I tried to fixate on a small

section of the screen. " "I searched within an area of about one square

foot. " "Entire screen" refers to those statements which indicated that

the S̲ tried to fixate on the whole screen, e. g. , "I focused on the whole

screen. " "Scanning" included those responses which indicated that the

S̲ searched or attempted to search the whole screen in some systematic

fashion, e. g. , "I searched back and forth across the screen, " "I scan-

ned the screen starting in the center and moved out in a spiral fashion. "

This table clearly shows that method of search was affected by

the length of slide exposure. With an exposure time of 0. 5 second,

most S̲s̲ were able to search only a limited area of the slide, while at

1.5 and 2.5 seconds, the majority of Ss were able to scan the slide.
This suggests that the major effect of increasing exposure time is to
allow Ss to search a larger area and thus to detect more of the letters.

Analysis of Preferences

Although the ratio of values for the two halves of the alphabet
were counterbalanced to eliminate the possible effects of preferences,
two analyses were run to determine if any preferences did, in fact,
exist. The dependent measures for these analyses were the percent
correct of first and second half categories and the percentage of initial
responses of categories within the first half of the alphabet. The 1:1
groups were included in these analyses since the objectives were to
analyze the effects of category halves and not differential value.

Except for the inclusion of the 1:1 group, the analysis of accuracy
for the category halves contained the same basic data that were used
in the analysis of correct responses to category value (Table 2).
Table 6 presents a summary of the results of the analysis on the arc sine
transformation of the percents. The significant effects of Exposure
Time (P < .01), Ratio of Values (P < .05), Load (P < .01), and
Load X Exposure Time (P < .01) do not add any new information since
the addition of the 1:1 group did not change any of those effects which
were already presented in Figure 2.

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Table 6
Summary of analysis of variance for biases in accuracy of report

SOURCE	df	MS	F
BETWEEN Ss	119		
EXPOSURE TIME (E)	2	40204.600	371.084**
RATIO OF VALUE (R)	4	319.250	2.947*
E x R	8	181.363	'.674
Ss/E x R[a]	105	106.344	
WITHIN Ss	1080		
LOAD (L)	4	32772.900	1658.888**
CATEGORY HALVES (H)	1	159.800	.903
L x H	4	280.050	11.168**
L x E	8	1660.413	84.046**
L x R	16	13.781	.698
H x E	2	429.400	2.425
H x R	4	114.700	.648
L x H x E	8	96.350	3.842**
L x H x R	16	10.269	.409
L x E x R	32	12.481	.632
H x E x R	8	165.625	.935
L x H x E x R	32	27.972	1.115
Ss x L/E x R[b]	420	19.756	
Ss x H/E x R[c]	105	177.047	
Ss x L x H/E x R[d]	420	25.077	

a ERROR TERM FOR E, R, E x R
b ERROR TERM FOR L, l x E, L x R, L x E x R
c ERROR TERM FOR H, H x E, H x R, H x E x R
d ERROR TERM FOR L x H, L x H x E, L x H x R, L x H x E x R
* P<.05
** P<.01

Although the main effect of Category Halves was not significant, the significant interaction of Load X Category Halves suggests that Ss did have biases. Figure 6 presents a summary of the results of the Load X Category Halves interaction. The figure does suggest a slightly greater preference for the first half of the alphabet with 4 and 6 categories on a slide, but over-all the preferences shown were essentially negligible and not systematic.

A summary of the significant interaction of Category Halves with Load and Exposure Time is presented in Figure 7. This figure suggests that preferences within the categories shift as exposure time is increased. This shift eliminated the first half preference with 4 and 6 categories and results in a second half preference for 8 and 10 categories. The preference with 12 categories did not change.

As with the initial responses to value, the preference in initial reports are not independent scores. This analysis was performed on the arc sine transformation of the percentage of initial responses to the first half of the alphabet. Table 7 presents a summary of the analysis of initial preferences. The only significant effects in this analysis were Load and Load X Exposure Time (P < .01).

Figure 8 shows the response to the first half of the alphabet as a function of number of categories (load). Values above 50% indicate a bias for the first half of the alphabet and those below indicate a second half preference. Inspection of this figure suggests that there
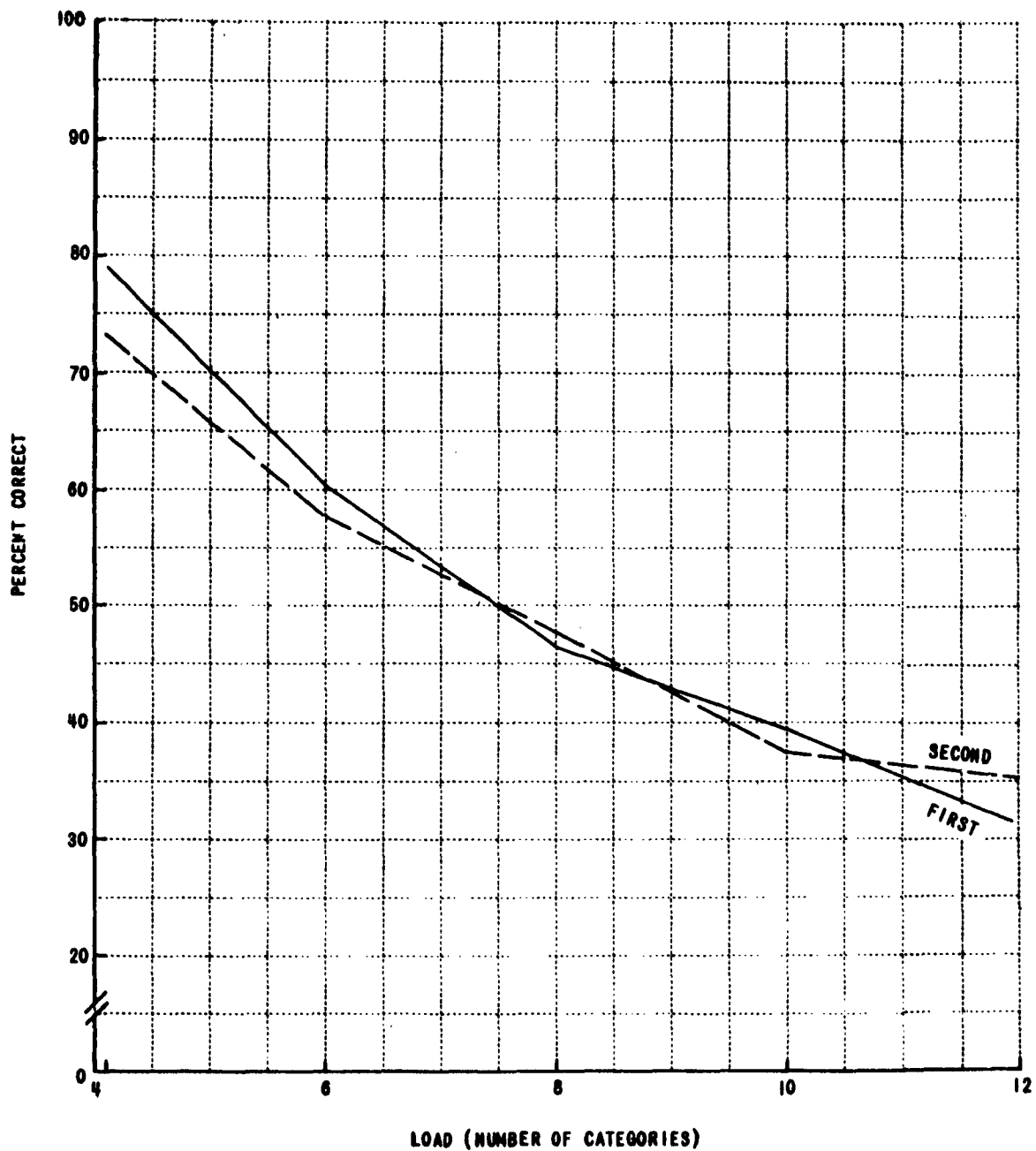
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Fig. 6   Percentage correct of categories within the first and second
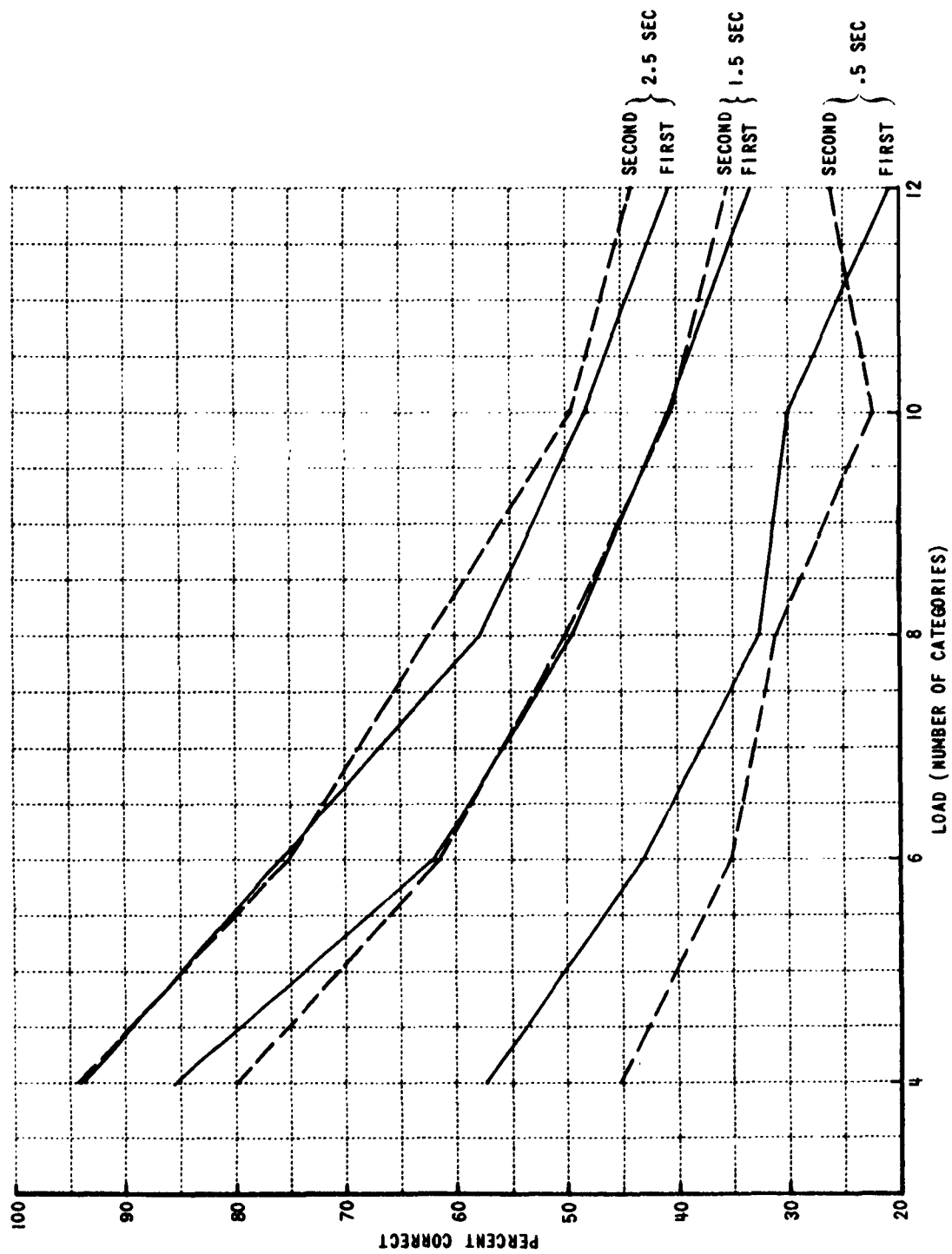halves of the alphabet as a function of load.

Fig. 7   Percentage correct of categories within the first and second halves of the alphabet as a function of load (number of categories) with exposure time as a parameter.

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Table 7

Analysis of variance for biases in initial response

SOURCE	df	MS	F
BETWEEN Ss	119		
EXPOSURE TIME (T)	2	6.30	.012
RATIO OF VALUE (R)	4	597.00	1.140
E x R	8	164.83	.315
Ss/E x R[a]	105	523.65	
WITHIN Ss	480		
LOAD (L)	4	2297.95	27.34**
L x E	8	225.99	2.69**
L x R	16	105.38	1.25
L x E x R	32	87.33	1.04
Ss x L/E x R[b]	420	84.06	

a ERROR TERM FOR T, R, T x R

b ERROR TERM FOR L, L x E, L x R, L x E x R

** P<.01
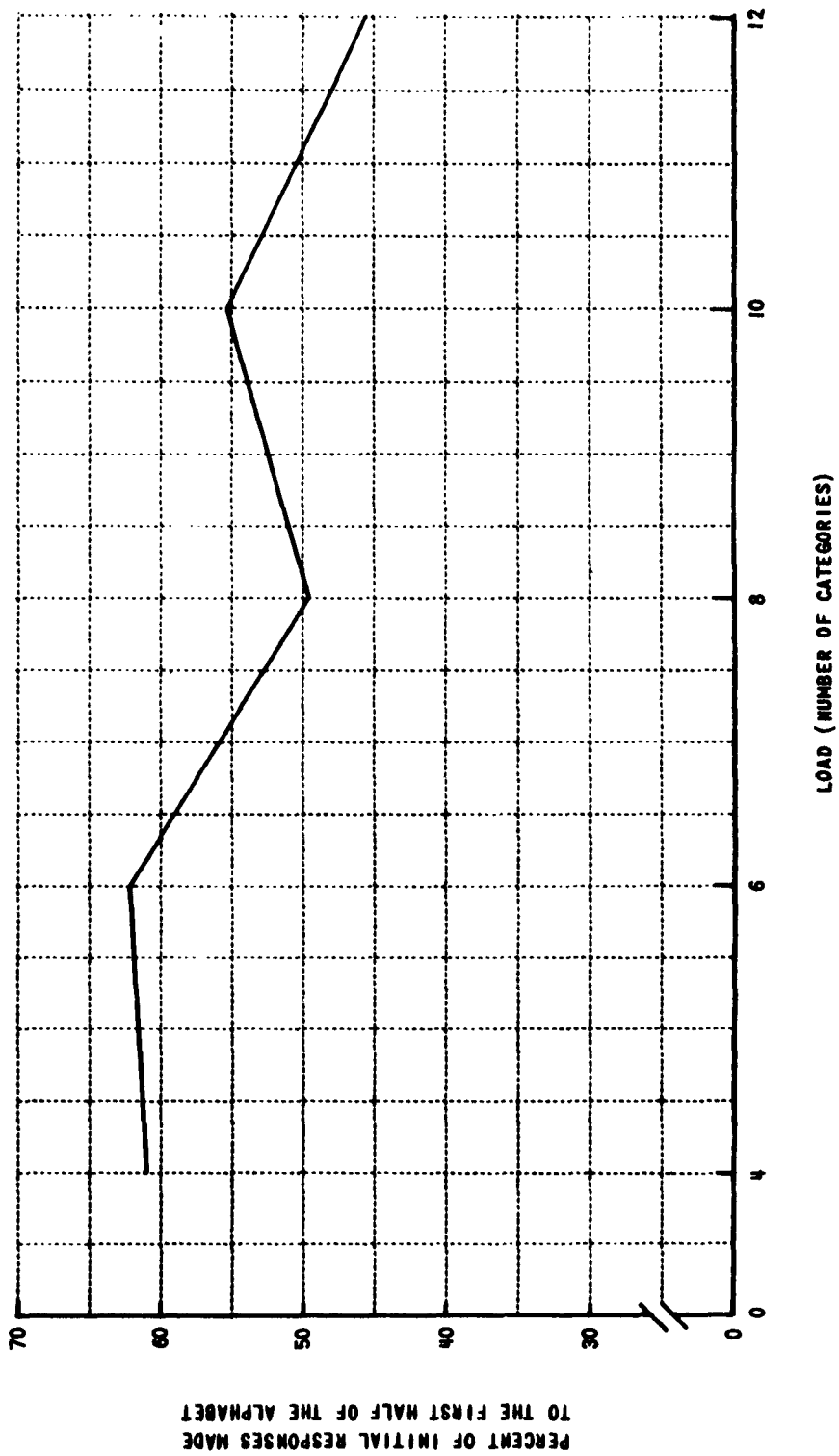
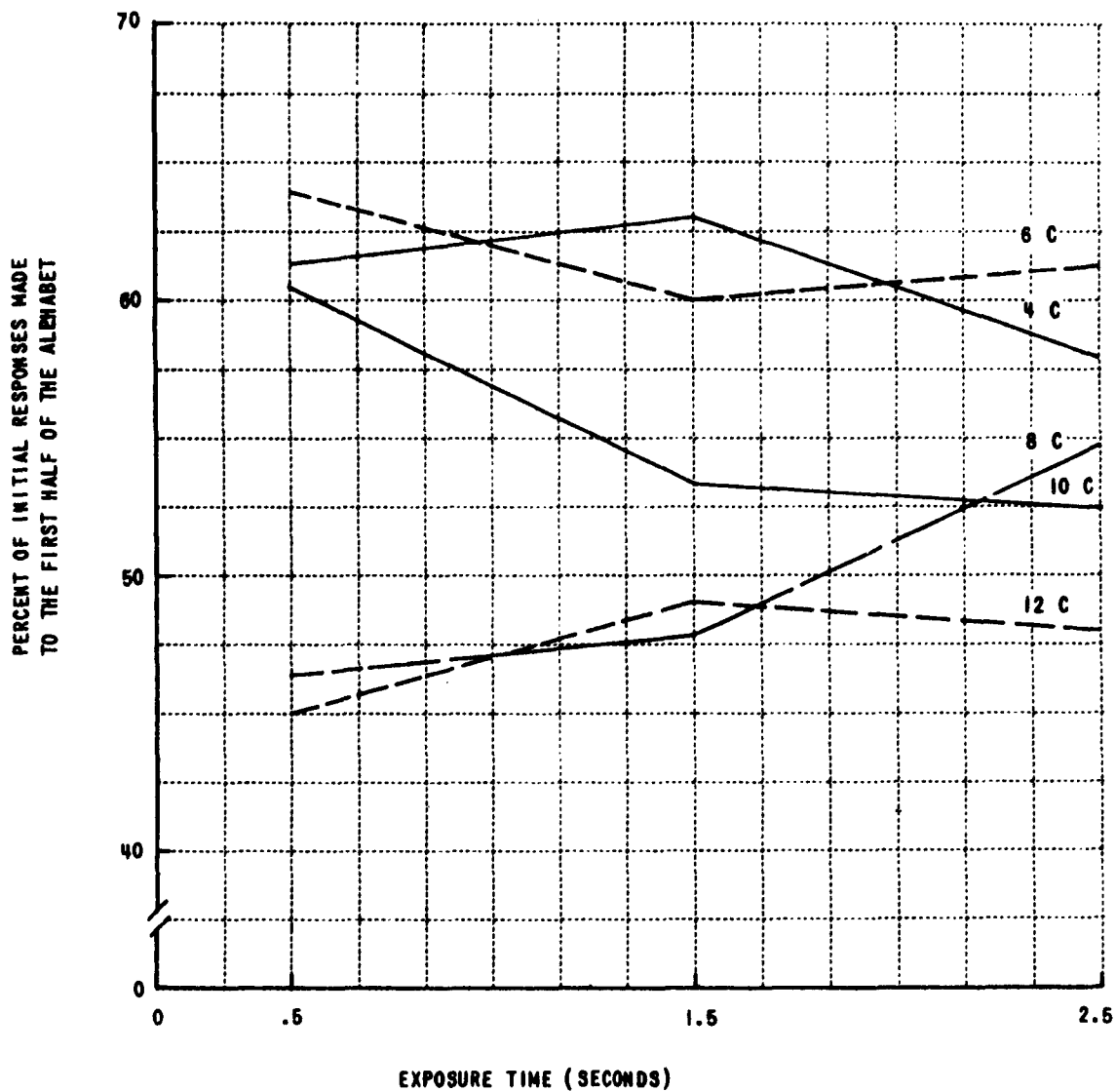Fig. 8 Percentage of initial responses of categories within the first half of the alphabet as a function of load.

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are first half preferences in initial response with 4, 6 and 10 cate-
gories, while there is a second half preference for 12 categories.
These preferences are in general agreement with those presented in
Figure 6.

The results of the Load X Exposure Time interaction do not
reveal any consistent trends. As Figure 9 shows, the only conclusion
which may be drawn from this interaction is that exposure time has
different effects with different levels of load.

Fig. 9   Percentage of initial responses of categories within the first half of
the alphabet as a function of exposure time with load as a parameter.

Discussion

The results of those effects which did not include value are
in complete agreement with previous studies (Teichner and Myers,
1961, 1962; Teichner, Reilly, and Sadler, 1961; Teichner and
Sadler, 1962). Thus, percentage correct varied inversely with the
number of categories and directly with exposure time. Further, the
benefit which was derived from increasing exposure time varied
inversely with load. That is, the greater the number of categories
displayed the less was the increment in accuracy derived from
presenting longer slide exposures. The agreement of the present
data with the previous results is of particular importance since any
inconsistencies would have made the validity of further findings
questionable. Thus, the present confirmation of the well established
findings of Teichner and associates lends confidence to the results
relating to differential value.

The data suggest that differential value did have an effect upon
Ss reports. Evidence for this effect comes from the fact that Ss
made more false reports, correct identifications, and initial responses
to the higher valued categories than to those of lesser value. These
differences are consistent with the general expectation derived from
previous studies and stated earlier as working hypotheses. In general,
the results are also consistent with the suggestion of Edwards (1961)
that monetary incentives serve as instructions that allow Ss to evaluate

the available courses of action. According to Edward's hypothesis, the points and monetary incentives served not only as motivators, but also provided $\underline{S}$s with instructions concerning the choice of strategies.

Although the results supported the hypothesis of differences in accuracy due to differential value, the ratio of value effect and the exact shape of the category value by ratio of value interaction were not predicted. The findings of previous studies indicate that the number of correctly reported stimuli remains invariant over a wide range of conditions (Sperling, 1960) and that percentage correct remains fairly constant for any particular exposure, load and density (Teichner and associates, 1961, and 1962). Using these studies as the basis for prediction, it was expected that over-all accuracy would remain fairly stable as ratio of value was increased. Further, in order to maintain a constant over-all accuracy, it was expected that accuracy with the higher valued categories would increase, while performance with letters of lesser value would decrease. The results suggest that although there was a decrement in performance for the lower valued letters, there was no corresponding increment for the higher valued categories. Further, this loss is accuracy without any compensating increment resulted in a decrement in over-all performance as the ratio of value was increased. Thus, the data suggest that an increase in differential ratio does not seem to facilitate reports of the more important targets, but rather inhibits the reports of less highly valued ones.

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The analysis of the initial responses supported the hypothesis that Ss would attempt to maximize performance by responding first to the higher valued stimuli. This was shown by the fact that with differential value, the percentage of initial responses to the higher valued stimuli was always greater than 50. Further, the percentage of these responses varied directly with the ratio of high to low value.

The only dependent measure which was not affected by increasing the differential ratio of value was the number of false reports. Although Ss made more false reports of higher valued stimuli, there were no significant changes with ratio of value. Considering the fact that the number of false reports did not vary with exposure time or with any interaction involving value, it would seem that this was not a sensitive measure in the present experiment. Further, the number of false reports were relatively small in comparison to number of correct reports or number omitted, i.e., the mean number of false reports was only 9.5 for a total of 50 slides. Thus in the present free search situation where there were no restrictions as to the number of responses and no penalties for false reports, Ss made only approximately 1 false report for every 5 slides that they observed. These results were contrary to the prediction based on the findings of a study using a threshold visual signal (Tanner and Swets, 1954). This discrepency in the data suggests that the present stimuli were not ambiguous or near threshold and thus the number of false reports was not greatly affected by changes in value and exposure time.

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Studies by Teichner, Reilly, and Sadler (1961) and Sperling (1961) have demonstrated that there is a difference between the amount of information received and stored, and the number of letters which can be recalled. Teichner and Myers (1961, 1962) assumed that every letter that is detected enters into the short term memory storage and that "recall" represents the difference between storage and memory loss due to some process going on in the storage. This assumption implies that the effect due to differential value may have occurred either before or after the development of a memory storage. That is, differential value may have affected either perception or recall. Since, in the present experiment, the measure of performance was recall or short memory residue, it cannot be determined whether the differential performance was the result of a selective perception of the categories or of a selective recall from memory storage. Thus although the general concept of maximization of performance may be applicable, the differences due to perception and loss from memory storage were not separable and the relative importance of these factors could not be evaluated.

On the other hand, the choice and arrangement of the stimulus materials were designed to minimize the effects of a selective perception. First, all letters were of equal size and were clearly visible and discriminable. Second, each slide contained an equal number of letters from the two halves of the alphabet. Further, the counterbalancing of the two halves of the alphabet with respect to differential value eliminated the effects of any preferences for

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particular letters within the first or second half of the alphabet. Other biases were reduced by the random selection of letters for each slide and the random positioning of letters on each slide. Finally, the high and low valued letters had an equal probability of being detected. $\underline{Ss}$ could not look at one particular part of the slide to detect the high valued letters and had to search the whole slide or as much as was possible within the limited exposure time. Thus, there would not seem to have been a way for $\underline{Ss}$ to perform any kind of selective process during the time that the slide was exposed. Since each slide contained an equal number of randomly located letters from the high and low categories, it can be assumed that an equal number was detected and that the differential effects were due to a selective decision which occurred after the development of memory storage. This selective process was assumed to result in an increased effort and a rearrangement or recoding of inputs in favor of the more important categories.

Although the above assumptions are in agreement with the present data, the possibility of a selective perceptual process has not been completely eliminated. If the assumptions of a selective memory process and the elimination of perceptual biases were incorrect and in fact there was a perceptual set for a particular group of categories, then these objects would be identified quicker and easier, would be given more often as false reports and would inhibit the identification of the other inputs (Bruner, 1957).

In consideration of this explanation, it would seem that exposure time is the variable which would be most critical for perception. If a

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selective process in perception were involved, then the size of the difference between high and low valued letters would vary inversely with length of exposure. This prediction is based on the assumption that perception should be more ambiguous at short exposures than at long exposures. Since a perceptual set for the higher valued letters would make these categories easier and quicker to identify, the major advantage of this perceptual readiness would occur at those conditions where there is less time to detect and discriminate between the categories. With longer exposure times there is more time for identification and both the high and low valued letters would be more easily detected and discriminated. Thus at short exposure times more of the high valued categories would be detected, while at long exposures all letters would be equally detectable.

The predictions from a selective memory point of view would be the opposite. Under short exposures, Ss would not have time to recode and the differences in response to value should be small. As exposure time increases and the rate of memory loading decreases, Ss have more time to act selectively to report the higher valued letters. Thus a selective memory process explanation would predict increasing differences in response to value as exposure time increases. Since the results support this latter hypothesis, the evidence is in favor of a major selective process between memory storage and recall.

Both the above results and the reports of Ss suggest that length-ening slide exposure does not seem to aid perception or decrease the ambiguity of particular letters, but only allows more letters to be

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detected through increased scanning. With a 0.5 sec. exposure most $\underline{S}$s could only fixate on a limited area of the screen, while $\underline{S}$s were able to scan the slide at 1.5 and 2.5 sec. exposures. Further evidence for the assumption that the perceptions were not ambiguous comes from the results of a study by Sperling (1961) using a non-search task. This study showed that there was no difference between 0.15 sec. and 0.5 sec. with respect to the number of letters which were correctly reported. Although a comparison of these two exposure times were not made under conditions of search, it seems reasonable to assume that differences would occur when search was involved. Thus it appears that if $\underline{S}$ looks at a letter, the letter will be perceived without ambiguity. Again it must be concluded that an equal number of high and low categories was detected and that the differential effect was due to selective reporting of the categories.

Further evidence contrary to the assumption of selective perception comes from the results of the analysis of false reports. As noted previously, the small number of false reports and the lack of significant changes with exposure time and ratio of value suggest that the present stimuli were not amgibuous. Although significantly more false reports were made to the high valued categories, the actual difference was less than 2 and would seem to be of little practical value.

Although the results are in agreement with the assumption of a selective memory process, there is a need for further research which would separate and control for the differences between the amount of information received (and stored) and the amount recalled. One method

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of accomplishing this test would be to utilize the procedure of Teichner, Reilly and Sadler (1961) in which one group of Ss had to report the names of the letters that they detected (naming group), while a second group had to report only the number of different letters (counting group). That is, the naming group had the same task of reporting each different letter as was used in the present experiment, while the second group had to remember and report just a single item (digit) and thus had a small memory requirement. In the test of the relative effects of value upon detection and recall, the two tasks would be compared with regard to the number of reported letters. The counting task, with its low memory loading would be used to evaluate the existence and size of a selective detection process, while the difference between this group and the naming group would be used to determine the effect of a selective memory process. An alternative method of approaching this problem would be to have complete knowledge of the stimulus by presenting only one letter per slide. The effects of memory load could be studied by requiring Ss to make their reports after a prescribed number of slides. For example, a measure of pure perception could be obtained by having Ss report after each slide is presented, while the measures of increased memory load would be obtained by presenting different numbers of slides before the letters are reported.

The analyses of the results for the first half of the alphabet versus the second half showed that Ss had small, but definite, biases. Further, the accuracy and initial response data both showed that these preferences differed with exposure time and with load. The fact that only small

preferences were obtained may have been due to the present coding

system which was large (22 letters) and was very familiar to the Ss.

It is possible that a different coding system which was smaller or less

familiar (e.g., colors, shapes, digits) might have resulted in larger

preferences. Although the present experiment was not concerned

with biases and in fact controlled them through the use of the counter-

balancing technique, preference effects may be important for the

choice of symbols in an actual work situation, i.e., the proper choice

of symbols to represent the high and low valued objects may enhance

the differences in accuracy of performance. Thus there is a need

for investigations of the effects of the size and type of coding system

upon detection and memory biases.

Summary and conclusions

One hundred and twenty Ss viewed a series of 50 slides which varied in number of letters. The letters were randomly chosen and randomly located for each slide with the restriction that all slides must contain an equal number of letters from the two halves of the alphabet. For each particular condition, each half of the alphabet represented a different value as defined by the number of points which may be received for a report of a letter within that half. The four differential ratios of value groups were 2:1, 4:1, 8:1, and 16:1. One third of the Ss within each of the ratio of value groups viewed each slide for 0.5, 1.5, or 2.5 sec. Consideration of the results of the present study suggest the following conclusions:

1. Accuracy of report of high and low valued symbols varies inversely with differential ratio of value. The data further suggest that an increase in differential ratio does not seem to facilitate reports of the more important targets, but rather inhibits the reports of less highly valued ones.

2. The difference in accuracy of report to the high and low valued letters varies directly with length of slide exposure up to 2.5 sec.

3. The percentage of initial responses (first letter which is reported by S) of high valued symbols varies directly with ratio of value.

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4. The data suggest that 1.5 sec. may either be an optimum exposure time or an asymptote of higher valued initial responses, i.e., there was no increase in percentage of initial responses to the higher valued stimuli when exposure time was increased from 1.5 sec. to 2.5 sec.

5. Number of false reports does not seem to be a sensitive measure when the stimuli are not ambiguous. Although more false reports were made to the higher valued categories, the number of false reports did not vary with ratio of value or exposure time.

6. The results support the conclusion that differential value produces a selective recall from short term memory storage.

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I. AF19(628)-290
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HQ ESD, L.G. Hanscom Field, Bedford, Mass. Rpt No. ESD-TDR-63-343
EFFECTS OF DIFFERENTIAL VALUE AND EXPOSURE TIME UPON THE DETECTION AND MEMORY OF SYMBOLS IN A VISUAL SEARCH TASK.
June 63, 48p.   Unclassified Report

The accuracy of reporting data from briefly-exposed, multi-target symbolic displays in which the value or importance of the targets varies within the display was shown to vary inversely with the differential ratio of value of the targets. The data also suggested that (1) an increase in differential ratio does not facilitate the reporting of more important targets, but rather decreases reports of less important ones, (2) the difference in accuracy of report to high and low valued targets varies directly with exposure time up to 2.5 sec. for the display used with 1.5 sec. as a possible optimum. The results are consistent with the hypothesis that differential value produces a selective recall from short-term memory storage.